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DIAMOND-DRILLING BLAST HOLES

EASTERN MAGNETITE MINE C

BY

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

DIAMOND-DRILLING BLAST HOLES, EASTERN MAGNETITE MINE C[1]/

By McHenry Mosier[2]/

SUMMARY

Diamond-drilling blast holes at Eastern Magnetite Mine C is proving economical in boundary shrinks, in removing pillars not readily accessible for percussion drilling, and in driving scraper drifts. The cost per foot drilled is greater than for percussion drilling, but savings in associated factors outweigh this handicap.

The rocks drilled include trap rock and magnetite ore.

The mining method is the panel, block-caving system utilizing scraper sublevel drifts instead of branch raises to convey the ore to the haulage level.

Diamond-drilling blast holes was begun early in 1945. Three rigs equipped with noncoring bits are now in active operation two shifts per day. They are owned by the company, and the drill operators are paid by the day. In shrinkage stopes the drill is mounted on a horizontal bar set against opposite walls of the stope. Stoping holes are horizontal, which gives better results in blasting and requires fewer set ups. In scraper drifts the drill is mounted on a horizontal bar clamped to two columns about 5 feet apart. Trim holes around the periphery of the drift and reliever holes are drilled 50 to 80 feet in length. A 10-foot wedge cut drilled with a stoper is blasted in conjunction with a corresponding length of the trim holes to effect a 10-foot advance of the full-sized drift. Recent drilling averages 97 feet per machine shift, excluding time utilized in setting up and moving the machine, hand mucking, and barring down. The feet drilled per bit at present is 417. These data represent the average for drilling in both rock (waste) and ore.

Percussion drilling utilizes three types of wet drills. Detachable bits are standard. Gage changes for new bits is 1/8 inch and for reconditioned bits 1/16 inch. The life of a bit is five uses. Resharpening is on contract. A drill carriage is used in haulage headings.

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7433."

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The advantages of diamond-drilling blast holes at Mine C include (1) greater safety, (2) better efficiency in driving boundary shrinks, (3) confined overbreak in blasting scraper drifts with resulting economy in concrete lining for ground support, and (4) elimination of dust from drilling. The disadvantages are (1) higher repair and maintenance costs for diamond-drill machines, which entail expensive delays at the face, and (2) loading and blasting long holes require greater skill and closer supervision.

INTRODUCTION

This paper is one of a series undertaken by the Mining Branch of the Bureau of Mines, Lowell B. Moon, chief, to describe current practice in diamond drilling for production purposes at various mines throughout the United States and to discuss the relative merits of this method compared with drilling by percussion rock drills.

The Bureau of Mines and the mining companies that are cooperating with it in this investigation have the common objective of developing information on this type of drilling and making it available to all who may be interested in improving mining operations.

The operating data, together with the photograph and sketches for the illustrations in this paper, were furnished by the staff at Mine C.

GEOLOGY AND ORE DEPOSIT

Magnetite ore carrying pyrite and some chalcopyrite occurs in lenses as replacements of shaly limestone overlying intrusive diabase, which is commonly called trap rock. The average vertical thickness of the ore body is about 100 feet, and its dip, although irregular, approximates 30 degrees. The hanging wall is composed of slate, conglomerate, sandstone, and quartzite.

MINING METHOD

The mine was opened by two inclined shafts in the foot wall of the ore body. One shaft hoists ore and the other handles men and supplies. These shafts are about 1,500 feet deep on the incline. The ore is mined by the panel block-caving system with scraper-sublevel drifts instead of branch raises, as formerly, to convey the ore to the haulage level. (See fig. 1.) Haulage levels are on 50-foot vertical intervals with haulage drifts in the foot wall along the strike of the ore body. Scraper drifts on 40-foot intervals are driven normal to the haulage drifts with a slope not exceeding 30 percent. Most scrapers operating in these drifts have 54-inch blades and move approximately 1 ton on each trip. They are pulled by an electric hoist with a 50-horsepower motor at a speed of 300 feet per minute. The return speed is 400 feet per minute. Cut-off shrinks 6 feet wide are stoped along the boundaries of the panel, except on sides that abut mined areas. The shrinks are driven to the hanging wall or to a maximum height of 95 feet above the floor of the scraper drift if the hanging wall has not been reached. Draw fingers on 20-foot intervals are raised on each side of the scraper

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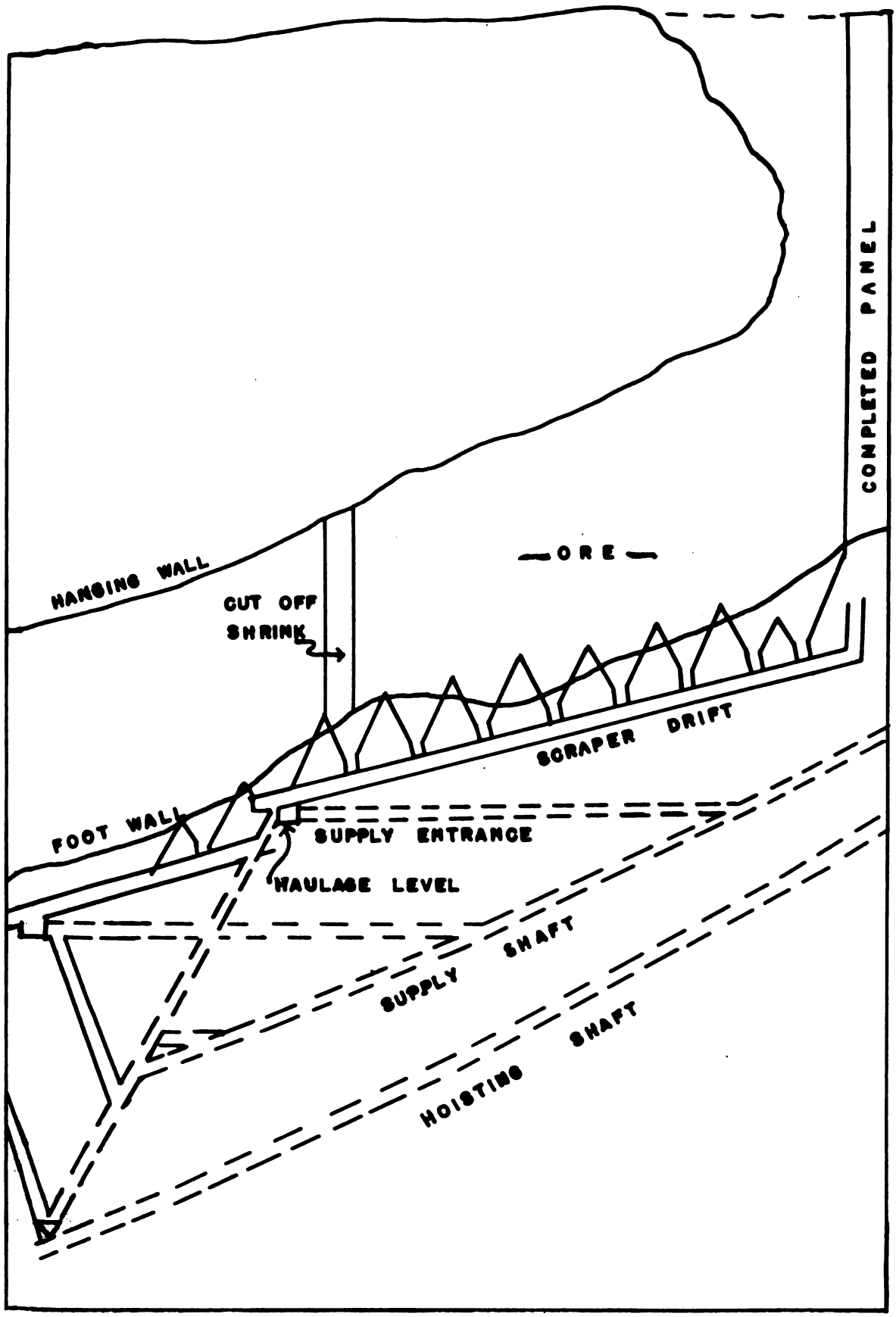

Figure 1. - Ideal cross section through active stope.

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drifts. The vertical distance from the floor of the drift to the bottom of the ore averages 40 feet. The tops of these fingers at the undercutting level are at the corners of 20-foot squares. Adjacent fingers are belled by shrinkage stoping until their rims meet. To provide access to the fingers during the process of belling, undercut drifts either parallel or normal to scraper drifts connect the tops of the draw fingers. Remnants of pillars that may remain between fingers are removed with the last cut in the belling operation. All the ore in any panel is drawn on a single lift.

Diamond drills are used for drilling blast holes in boundary shrinks and in scraper drifts. They are also used on the undercut level along the boundaries of the panel to extract pillars too large to be readily accessible from finger raises. Additional blast holes in the back adjacent to these pillars, may be diamond-drilled to promote caving.

Diamond-drilling was tried in belling operations in finger raises but was discontinued because this method did not assure thorough or complete undercutting of the entire panel. Furthermore, inspection after blasting on the undercut level was not feasible. Consequently, when a round failed to break properly, the stope would hang up, and then it became difficult to remedy the situation.

Blasting in boundary shrinkage stopes is with a detonating fuse and a semigelatin dynamite having a strength of 40 percent. In development headings, 40 percent dynamite is detonated by No. 6 blasting caps and safety fuse.

Mine haulage is by 250-volt trolley locomotives, which are rated at 4 tons but have been weighted to 8 tons by loading with 1-inch boiler plate. Five-ton, solid-bottom, side-dump cars are run in 5-car trains on 60-pound rails over a maximum haulage distance of 1,100 feet. Electric-light signals to show the location of haulage trains on laterals at stopes are automatically controlled by an interlocking device attached to the switch throws on the main-line track. The track in the loading areas at stopes is cleaned by mechanical car loaders.

Hinged safety doors operated by compressed air cover ore dumps at the shaft. Cars are dumped by a piston actuated by compressed air in a 12-inch cylinder.

DIAMOND DRILLING

Equipment

Diamond drilling blast holes was started at this mine early in 1945 with one experiment drill. Three rigs now are in active operation on blast holes, two shifts per day. They are owned by the company, and the drill operators are paid by the day. The crew for each drill is comprised of a driller and a helper.

The drills have the following specifications:

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	A	B
Manufacture		
Number of drills in service	2	1
Air motor:		
Type	Rotary	Rotary
Horsepower at 80 pounds air pressure	5	10
Feed:		
Type	Screw	Screw
Length of feed, inches	24	27
Revolutions per inch of bit advance	200-500	200-600
Bit speed (range, r.p.m.)	0-2400	0-3300
Weight of machine (pounds)	160	155
Capacity (E rods, feet)	500	500

E rods are used exclusively for all blast-hole drilling. They are 2 feet long. Bits have an outside diameter of 1-13/32 inches, which is 1/16 inch less than standard EX. They are noncoring, either in a pilot or concave pattern. Both patterns are used in ore and trap rock. The concave bit drills better in limestone, but the pilot bit penetrates hard ore faster. One manufacturer sets 20 to 25 stones in a bit with a total of about 10 carats in the concave bit and 11 carats in the pilot bit. Another manufacturer sets 30 to 35 stones in a bit, with a total of about 8.5 carats in the concave bit and 12 carats in the pilot bit. The stones are best-quality AA-grade diamonds. They retailed at $6 per carat prior to June 1946, but in April 1947 they sold at $7.40 to $9.00 per carat.

The angles for drilling are established by the drill operator with a machinist's protractor and level.

A core barrel is used only for long holes in drifting operations in trap rock, where it tends to keep the drill hole straight. In holes less than 100 feet deep, the error caused by wandering of the bit is small and is less than that due to the alinement of the machine in pointing the hole. In other drilling operations a hard-surfaced adapter is used between the E rods and the bit in lieu of a core barrel. It has a length of 12 inches and the same diameter as a standard blank reamer.

Tamping sticks in conventional 4-foot sections slotted, bored, and threaded with sash cord are used on horizontal holes. For steep up holes the 4-foot sections are connected by short strips of rawhide.

Air pressure is 100 pounds per square inch at the compressor and 85 to 90 pounds at the machine. Water pressure can be regulated to suit conditions. For drilling in ore, it averages about 125 pounds per square inch.

Set-up

In boundary shrinkage stopes the drill is mounted on a horizontal bar set against opposite walls of the stope. Horizontal holes have proven more satisfactory than vertical holes. Better results are obtained from blasting, less development drifting is required, fewer set-ups of the diamond drills are necessary, and more footage can be drilled from each set-up. Holes are 80 to 90 feet in length. They are drilled on 3-foot centers horizontally in

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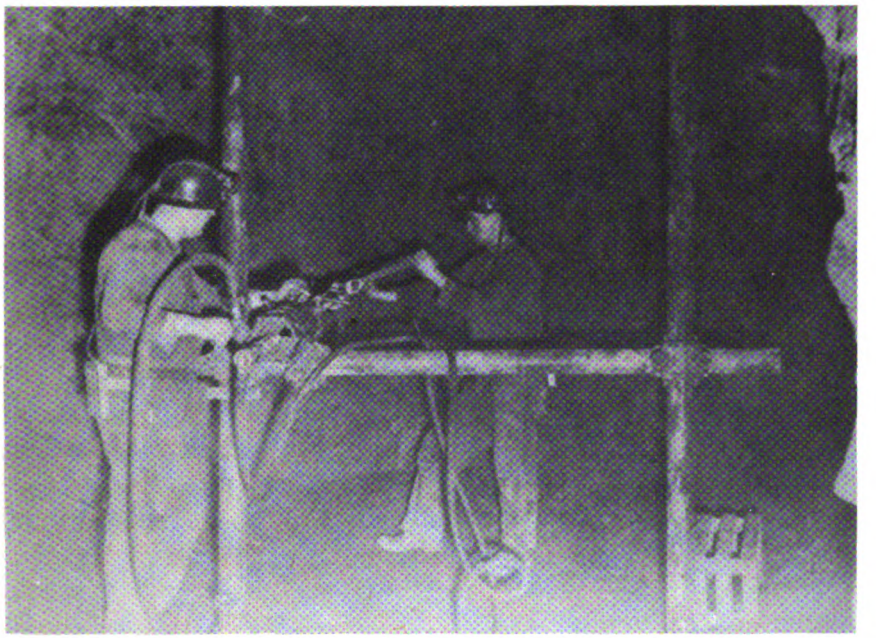

Figure 2. - Diamond-drill set-up in scraper drift.

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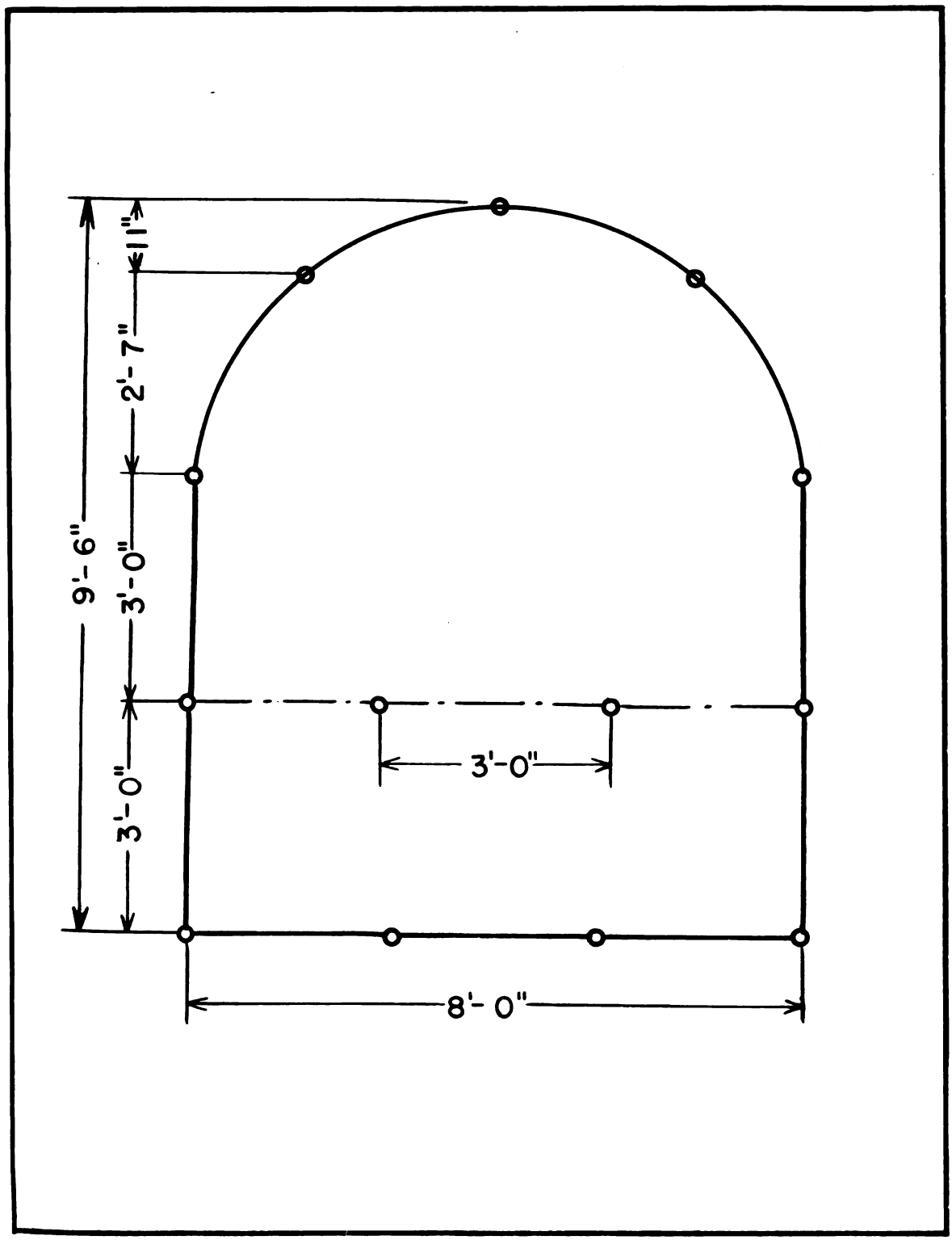

Figure 3. - Diamond drill rounds for scraper drifts.

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rows spaced 3 feet vertically on two sides of the finger-raise manways that have been extended into the ore body. Three holes are drilled from one side of the horizontal bar; the machine is reversed, and three holes are drilled from the opposite side. The bar is then reset for drilling the next row of holes 3 feet higher. As the shrinkage stope progresses upward, the manway raises are enlarged by blasting stoper-drill holes to form additional diamond-drill stations.

In connection with horizontal drilling, much of the work of barring down the back of the stope is eliminated, because work in the stope is confined to diamond-drill stations. Because men do not enter the remainder of the stope, only the diamond-drill stations are required to be made safe.

In scraper drifts the drill is mounted on a 4-inch horizontal bar 7 feet long, fastened by universal clamps to two 4-inch, double-screw columns about 5 feet apart. (See fig. 2.) The columns, which are 12 feet long, are plumbed and placed so that the bar is at right angles to the line of the drift. They are set by the driller from survey alinement spads by means of a carpenter's square, but are checked by an engineer with a transit. The drill is then mounted, and the swing is clamped so that all holes will be drilled in the same direction as the drift.

Most scraper drifts have a length of about 100 feet. The first half, or lower section, only is diamond-drilled because of the convenience of the set-up of the diamond drill near the haulage level. Also, as head room for the diamond drill station is gained by cutting the floor below grade, this depression can be utilized after stoping begins to accumulate several additional scraper loads of ore for each trip of the haulage train.

In driving scraper drifts, 11 trim holes around the periphery of the drift and two reliever holes in the lower part of the face (see fig. 3) are drilled 50 to 80 feet in length. The noise level is reduced through the use of a 15-foot tail hose on the exhaust. A 10-foot wedge cut comprised of four stoper holes in the upper half of the face is blasted in conjunction with a corresponding length of the trim-holes to effect a 10-foot advance of the full-sized drift.

Results

Operating data for all diamond drilling in stopes and drifts since its inception at Mine C are below:

Period	Feet drilled	Machine shifts	Feet drilled per machine shift
1947 (2 mos.) ...	2,040	21.0	1/97.1
1946	38,052	516.5	2/73.7
1945	46,158	709.5	2/65.1

The average depth of hole was 45 feet and the maximum 100 feet.

1/ Excludes time utilized in setting up and moving the machine, hand mucking, and barring down.

2/ Includes time utilized in setting up and moving machine, hand mucking, and barring down.

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Further data on bits, including cost of reconditioning them, follow:

Item	A[1]	B[2]
Feet drilled per bit	251	417
Diamond wear per foot drilled (carats)	0.0124	0.0038
Total cost bit replacement per foot drilled[3] (dollars)	0.100	0.056

1/ Based on 63,266 feet of drilling in 1945 and 1946, for which data on bits are available.
2/ Based on 22,108 feet of drilling in the latter part of 1946.
3/ Includes cost of replacement of diamonds on former basis of $6 per carat, new blanks, resetting bit, postage, and insurance.

A material economy in driving scraper drifts with diamond drills has resulted from the saving in the amount of concrete used in the lining for ground support. Ready-mixed concrete fed by a 3/4-yard concrete placer at the collar of the shaft is dropped from the surface through a 6-inch pipe in the shaft to a hopper at the shaft station. It is then pumped to the scraper drift, where collapsible steel forms have been installed in 5-foot sections.

The change from percussion drilling to diamond drilling has reduced the overbreak so that only 1 cubic yard of concrete lining is required for each linear foot of drift, whereas 1.5 cubic yards formerly was necessary. This improvement is due to better alinement of the diamond-drill holes in comparison with the former drilling practice with drifter drills.

PERCUSSION DRILLING

Three types of wet drills are in operation at Mine C. Drifters use 1-1/4-inch round-lugged steel; stopers, 1-inch quarter octagon and sinkers, 7/8-inch quarter octagon. Detachable bits are standard. New starters are 2-1/8 inches in diameter, whereas reconditioned starters are 1-3/4 inches in diameter. The gage change for new bits is 1/8 inch and for reconditioned bits 1/16 inch. In ore, 6 bits are the normal quota for a shift's drilling, but in waste rock a complete set is required for each hole. When issued to miners, bits are threaded on a wire loop having a maximum capacity of 30 bits. The life of a bit is five uses. The original bit is returned to the factory for four resharpenings on contract at a fixed price.

In development drifts, a 6-foot round with 18 holes is drilled by a 3-man crew with two 3-1/2-inch mounted drifters. One crew mucks, stands the column, and sets up the drill. The crew on the following shift drills, loads and blasts. In haulage drifts with a cross section of 10 by 10 feet, four machines mounted on a drill carriage complete an 18-hole, 7-foot round in trap rock in 1 hour. One detachable bit is dulled on each drill run of 24 inches.

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RELATIVE MERITS OF DIAMOND-DRILLING BLAST HOLES AT MINE C

The advantages of diamond drilling blast holes are:

1. Greater safety in boundary shrinks because work is confined to drill stations.

2. Better efficiency in boundary shrinks because fewer men can break the ground at greater speed.

3. Pillars that are not readily accessible for percussion drilling can be extracted safely.

4. Virtually no overbreak in blasting scraper drifts, with resulting economy in concrete lining for ground support.

5. Elimination of dust from drilling.

On the other hand, the disadvantages of diamond-drilling blast holes at this mine are:

1. Higher repair and maintenance costs for diamond-drill machines, which entail expensive delays at the face.

2. Loading and blasting long holes require greater skill and closer supervision.

CONCLUSIONS

Diamond drilling blast holes is proving safer and more economical in driving boundary shrinks with long horizontal holes than by conventional procedure with percussion drilling. In scraper drifts, the economy in concrete lining as a result of confining the overbreak more than offsets the higher cost per foot for the diamond drilling.

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